SCIENCE

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SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS
New York City: Grand Central Terminal

Lancaster, Pa. Garrison, N. Y.
Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

A STUDY IN BIOKINETICS

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I. IS THERE A STANDARD UNIT OF MEASURE FOR PHYSIOLOGICAL ACTIVITIES?

No biologist will deny probably that the conceptions of the cell and gene as biological units have been of great value in the understanding of development, growth and heredity of living things. These concepts are doubtless as fundamental and indispensable to the morphologist as the concepts of molecule and atom are to the chemist. However, in the field of physiology, the aim of which is function rather than form, one seeks in vain for a unit of similar significance. The reason for this lies partly in the lack of control, and, if not in control, in the statement of experimental conditions.

For example, if one wishes to gather from the literature on heart metabolism the determinations of carbohydrate and oxygen consumption and to reduce them to a common basis for comparison, one finds the task almost hopeless. For some one or another important condition or factor of the experiment has usually been omitted in the report. The results may be given in grams or cc per unit of time, but the rate of beat, or the maximum tension exerted, or the weight of the contracting mass, or the temperature has not been definitely stated. How then is one to compare the metabolism of one heart with that of another, to say nothing of a comparison of the metabolism of heart muscle in general with that of skeletal and smooth muscle? If a number of reliable observations, say, on the carbohydrate and oxygen consumption of the various kinds of muscle could be reduced with certainty to the weight of these substances used up per gram of muscle, per gram tension exerted, per single contraction, one would begin to feel that one had the materials for a search for a common standard of measure of muscle activity, and indeed a promise of finding a common standard of measure for all vital activities; the point being that a smallest unit of vital activity first must be recognized and agreed upon, and second that the observed meta-

bolic changes are reducible to that unit. On such a basis the possibility can not be excluded that ultimately physiologists may find a reliable yardstick for the final comparison of any one with any other elemental physiological process—a unit of measure that will serve finally even in the analysis of the more complicated mechanisms.

It should be noted at the outset that this unit is no philosopher's concept of an *élan vital,* or an *entelechie* —of a vague but indispensable essence of *bios.* On the contrary, it must express definitely the energy of the smallest activity that can be recognized and agreed upon as physiological, as peculiarly living, as opposed to the activity of non-living matter.

If such a standard does not exist or defies analysis and definition it would seem that we shall be obliged to abandon for all time any hope of carrying our analysis and description of the physiology of living matter much beyond the point where we have now arrived.

Modern physiologists thus far have been quite content, and rightly so, whenever they have been able, to take the measure of a living process in terms of the units set up as standard by the physicist and chemist. For the most diverse phenomena of the non-living world have been brought together under increasingly inclusive concepts and thus have been expressed in more comprehensive units of measure. Indeed it is a striking fact that the physicist and chemist have been able to arrive at their most far-reaching generalizations only in so far as they have been able to marshal their specific measurements under broader and more inclusive standards of measure. In his preliminary study, therefore, the physiologist perhaps can do nothing better than to inquire as to how far he is able to marshal the diverse and special measurements of various living processes similarly under broader and more inclusive standards. And if these more inclusive standards turn out to be also merely the standards set up by the physicist, he still may feel justified in having made the attempt and in believing that the goal of standard unit of physiological activity has been brought thereby somewhat nearer to realization. Accordingly what follows in the present paper consists of a preliminary examination of the field to that end.

II. On the Nature of Excitation

All physiology may be defined simply as a study of stimulation and response of living matter. But stimulation is the process of arousing a state of excitation at a given point, and since all response is preceded and accompanied by physiological excitation our definition may be simplified further by saying that all physiology is a study of the excitation of living matter. Is there any property or process common to all the manifold forms of excitation, of conduction and response, that physiologists thus far have studied? The answer to this question is decidedly yes. For in every case where the tissue can be tested by appropriate experiment the excitation aroused by a stimulus has been found to be accompanied by an electrical disturbance, long known as the "action current," more lately referred to as the "action potential" both phrases leaving the word "electrical" to be inferred. This is true not only for the immediate region of excitation, the receptor or sense organ, but for the conducted wave of excitation be it along a nerve fiber or over a muscular organ, or any other excitable tissue. Just recently this electric change has been observed for single muscle and nerve fibers and finally for a single sensory-end point such as the so-called muscle spindle. There can be no doubt that it will be demonstrated finally for such excitations as the contraction of the vorticella stalk and of a single flagellum of the flagellates.

The newer physics teaches us that the setting up of a difference of electrical potential is due to the pressure of negatively charged particles called electrons; that the electrical current is a transfer, or a flow of these electrons in one direction and that the free electrons move with great speed in an oscillatory or vibrational manner.

Excitation of living matter therefore must be at bottom a tearing loose and transfer of electrons. How is it possible for the many varied forms of stimulation (which we know are able to excite living matter) to excite electrons? For the answer we must examine the various forms of external stimuli themselves. When this is done it is found that they also are vibrational in character, molar, that is made up of molecular vibrations in the case of mechanical, sonic and auditory stimuli, and thermal stimuli when these are due to conducted heat. In the case of electricity and radiated heat, in short, in case of all forms of radiant energy that serve as adequate stimuli to living matter, these all are obviously vibrational in character. These widely different forms vary in wave-length from nearly two meters to a fraction of a mm (as in the case of mechanical and sound stimulations) to the exceedingly short wave-length of the visible, ultra-violet and Roentgen rays. How can stimuli of such various wave-lengths set up electron transfers?

Before answering this question it is worth while noting that, so far as we know, living matter is not stimulated by radiant energy of all wave-lengths; for example, the Hertzian, or "radio" waves, the electromagnetic waves and the shortest of all known, the cosmic rays, produce no stimulation. It will be noted that some of these non-stimulating waves have longer,

some shorter, wave-lengths than, say, the visible which probably affect all forms of life. In other words, there are not only islands of deafness in certain ears but in all living matter there are islands of irresponsiveness to certain groups (or octaves) of the great keyboard of vibrational energy.

The explanation of this is given with the answer as to why living matter is excited at all by any vibrational energy. Clearly this must be because living matter contains resonators or "detectors" that "synchronize" with certain wave-lengths and thus excite electrons in the living body. Hence we have the "action currents," the "action potential" in the living body accompanying all forms of excitation, that is all forms of effective stimulus and response.

An effective and adequate stimulus, therefore, must be vibrational in character. But before leaving this definition it should be pointed out that one other characteristic is also a *sine qua non*. There must be a certain suddenness in the change, a certain minimal rate of change, in the intensity of the external stimulus. This explains further, perhaps, why living matter is insensible to certain forms of radiant energy mentioned above. We can move from the dark into the light but when do we ever move out of or into the terrestrial field of magnetism? These magnetic waves are all-pervasive and their rates of change in intensity are of the slowest. The cosmic rays likewise are always with us at the same intensity so far as we know. Living matter has had no occasion to develop appropriate resonators to detect them and would have no use for them if it did.

All living matter is at times irritable, and sensory end-organs are only masses of living matter specially organized in different ways to exhibit extreme degrees of irritability, that is, to play the rôle of resonators to changes in intensity of various forms of vibrational energy.

We now then begin to perceive what some of the conditions of a living tissue must be when in a state of irritability. Irritability requires a difference of electrical potential set up between the two sides of an interface in such a state of equilibrium of surface forces as to be vulnerable to a sudden change of certain vibrational intensities. When this latter effects an electron transfer, then an adequate stimulus results, the action potential is observed, the excited state is set up, in some cases propagated, and finally motor end-organs are likewise excited.

From what has been said in the foregoing section it no longer appears unreasonable that, at least in some of the physiological processes, we are dealing with radiational forms of energy and electron transfers. If this is the case then the question becomes pertinent: Do any of the laws of radiation, as developed by the modern physics, hold in the case of such physiological activities? Before answering this question it is in order first to make a brief statement of such laws and equations as will be made use of in the answer.

III. Laws of Radiation and Biological Processes

The law of equivalence as formulated by Einstein states that for every molecule or atom undergoing change in photochemical reaction one quantum of radiant energy, $h\nu$, is absorbed. If q' represents the total absorbed light energy in terms of ergs, and N the total number of molecules or atoms engaged in the reaction then

$$(1) \qquad q' = Nh\nu, \text{ ergs; whence } q'/Nh\nu = 1.$$

This equation has been verified for certain photochemical reactions. For certain other photochemical reactions, where the equation does not appear to hold directly, reasons have been given to show that the observations dealt not with the primary photochemical reaction but with "secondary" and even "chain" reactions; indeed in several of the exceptional cases, in which the primary action was finally found, the law of equivalence was also found to hold. At the present time it is said the law of equivalence has been found to hold for some 28 photochemical reactions; there are a number in which the primary action has not yet been discovered.

Stark in 1908 first gave evidence that such a law existed for photochemical reactions and Einstein, of relativity fame, put the equation on a firm theoretical basis (1912). The physicist, E. Warburg, (1912–14) gave the first complete experimental proofs that the law holds, work that was promptly followed by numerous other confirmatory experiments during the score of years that now have intervened. The physical-chemists were interested from the beginning; and to some of them, notably Bodenstein, Trautz (1904–1918), Haber, C. M. Lewis and Perrin (1919), among others, it occurred that if photochemical reactions are a function of the frequency of the effective visible and ultra-violet wave-lengths then it may be that thermochemical reactions are likewise a function of the frequency of the respective wave-lengths that lie in the infra-red portion of the spectrum.

The equations expressing the relation between temperatures, heat of activation and velocity of reaction for ordinary chemical processes, that go on independently of light, had been determined long before; but now it was advocated, for instance, that an equation expressing the relations in a thermochemical reaction based upon the laws of radiation was nothing more or less than that of the well-known equation expressing the velocity of a reaction as influenced by temperature. Thus it was pointed out by M. Trautz and by J. Perrin that the equation

(2) $$\ln K = \frac{h\nu}{k}\left(\frac{T_1}{1} - \frac{T_2}{1}\right)$$

(in which K is the velocity of the reaction; ν, the frequency of the effective wave-length; k and h, radiation constants; T_1 and T_2, temperature in degrees absolute) is practically nothing more or less than the van't Hoff equation,

(3) $$\ln K = \frac{q}{2}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

in which q in terms of calories of heat (instead of $h\nu$ in terms of ergs) is the critical increment of energy required per gram-molecule of the chemical substance activated.

Now this q factor of equation (3) has been a subject of study for a number of years by both chemists and physiologists, for obviously it can be determined if one only observes the velocities of the reaction (k) at different temperatures. The physiologist reasons that if q represents the amount of energy required per gram-molecule of substance undergoing chemical change in a purely chemical reaction, then likewise q determined from the observed velocities of certain biological processes at different temperatures will also represent the required energy per gram-molecule undergoing chemical change in the living body, even though just what the chemical change is, may not be known.

Do the q′ and q terms of the two equations, (1) and (3), stand essentially for one and the same thing? Are they equal and interchangeable? Theoretically in (1) q′ is the total increment of energy required for activation of a gram-molecule of substance undergoing photo-chemical reaction while in (3) q is the total increment in energy required for activation of a gram-molecule of substance in a thermochemical reaction. Is the energy here involved in the form of radiant heat or of conducted heat? Increase of temperature involves an increase in the speed of motion of the molecules of the body heated, causing increased number of molecular impacts and bombardments. Arrhenius considered this but could not find enough energy from this effect to account for the enormous influence that a rise of temperature has upon the velocity of reaction and rejected it as an inadequate explanation of the phenomenon.[2a] This forces one to turn to the radiant aspect of the heat for an explanation.

The champions of the radiational hypothesis of thermal-chemical activation, therefore, believed themselves justified in assuming that the jump in the frequencies from the lower to the higher temperatures represents a critical increment of energy in the sense of that phrase as used by the exponents of the radiational theory of photochemical reactions, and that actual electron-transfers thus are effected in the thermal as well as in the photochemical reactions. If so, then q′ and q of equations (1) and (3), if not equal, can be made so by introducing a correcting factor, as Perrin, among others, did and as appears in the constant of equation (2).

According to Wien's law of displacement, wave-length and therefore frequency of radiant energy, is a function of the temperature and expressed by the equation,

(4) $$\lambda\mu T = b$$

But, $c/\lambda\mu = \nu$, and therefore the law of equivalence as expressed in equation (1) may be put as

(5) $$q' = NhCT/b, \text{ where}$$

N is Loschmit's number, or the Avogadro number, $= 6.06 \cdot 10^{23}$
h is Planck's radiational constant, $= 6.55 \cdot 10^{-27}$,
C is the speed of light in μ, $= 3 \cdot 10^{14}$, and
b is the constant in Wien's law, $= 2882$.

When the constants in (5) are put in a single figure, we have

(6) $$q' = 41.2 \cdot 10^{7} \cdot T \text{ ergs.}$$

For those chemical reactions and for those physiological processes, that are influenced by temperature in their rates of reaction, it has become customary to reduce the observed results of observations to a common standard, that is, to a temperature coefficient for differences of ten degrees, expressed with the symbol, Q_{10}. If Q_{10} is known for a given process the determination of q is simplified. For, from equation (3) it follows that in the special cases where the velocities of reaction are k_2 and k_1 at temperatures T_1 and T_2, when the latter are 10 degrees apart, $k_2/k_1 = Q_{10}$. Then, introducing the necessary modulus to convert natural into Briggsian logarithms and also the factor $4.19 \cdot 10^{7}$ to convert calories into ergs, equation (3) becomes

$$q = \log Q_{10} \cdot 4.57 \cdot \frac{T\,(T+10)}{10} \cdot 4.19 \cdot 10^{7} \text{ ergs.}$$

By taking a temperature that is median to T and T + 10 (say, Tm) we have an approximation equation out of (3) where

(7) $$q = 1.915 \cdot 10^{7} \cdot \log Q_{10} \cdot T^{2}_{m} \text{ ergs.}$$

But Q_{10} varies between 2 and 3 for the most part. If we put $Q_{10} = 2.5$, then equation (7) takes the special and simple form of

(8) $$q = 0.761 \cdot 10^{7} \cdot T^{2} \text{ ergs.}$$

[2a] But see also the papers of K. F. Herzfeld, *Ann. der Physik.*, 1919, vol. 59, p. 635, and *Zeitschr. f. Physik.*, 1922, vol. 8, p. 132.

The Einstein photochemical equation in the form of (6) may now be compared easily with the van't Hoff-Arrhenius thermodynamical equation in the form of (8).

Physiological reactions among the cold blooded animals proceed mostly between 5 and 25 degrees C, and in this range, even for one and the same reaction, Q_{10} may vary from 3 to 2. Below I have tabulated the values of q in terms of 10^{11} ergs as calculated from the photochemical equation (6) and also from the thermodynamical equation (7). In both cases the calculation is made for the median temperatures, at which the corresponding values of Q_{10} are sometimes found, and on the assumption that a purely radiational effect could be had at the infra-red frequencies represented by the given temperatures. In the last column the ratio of q/q′ is given for each of the temperatures; from definition this is also the value of q/Nhv.

TABLE 1

T_m, degrees absolute	Q_{10}	Energy in terms of ergs/10^{11}		$\frac{q}{q'}$
		q	q′	
283	3.0	10.66	1.164	10.94
288	2.5	6.31	1.186	5.33
293	2.0	4.69	1.206	3.85
303	1.0	0	1.249	0

It is quite obvious thus that in this range of temperature q in the thermodynamic equation varies greatly, that is, roughly as the square, or as the logarithm, of the temperature coefficient (when this latter varies); whereas q′, as determined from the photochemical equation, varies just linear with the temperature. The table finally shows that, when $Q_{10}=1$, then $q=0$; whereas q′ is still in quite linear proportion to T. This simply emphasizes the point that in purely photochemical reactions a rise of temperature (in the sense of heat conducted to the system, which latter thereby becomes a warmer body) has no effect whatever on the reaction.

When biologists began to point out that those physiological processes having a temperature coefficient lying between 2 and 3 were probably processes primarily dependent upon chemical reactions, the objection was raised that such was not necessarily the case because some (photochemical) reactions have their $Q_{10}=1$. This argument led these critics into the fallacy of implying that, because some chemical reactions are not influenced in their rates by temperatures, those reactions that are so influenced can not be chemical reactions!

But let us take a case where the temperature coefficient is nearly constant throughout the range of temperature employed in the foregoing table, say $Q_{10}=2.5$. Putting q and q′ again in terms of ergs/10^{11} we see that the q values vary with the temperature in the same linear fashion, as do the q′ values.

TABLE 2

T_m	q	q′	q/q′
278	5.88	1.144	5.14
283	6.06	1.164	5.21
288	6.31	1.186	5.33
293	6.54	1.206	5.42

In table 1, last column, one sees that the ratio q/q′ also tends to be constant.

This ratio shows that when $Q_{10}=2.5$ the energy involved in the thermodynamic equation is some five times greater than that involved in the radiational equation. Does this mean that in the former reaction there are some five quanta of the infra-red radiations absorbed per molecule that undergoes chemical transformation? Or does it mean that the chemical reaction can be accelerated merely by the increase in the rate of molecular impacts? In this latter case, then, it takes five times the energy when applied in the form of molecular impacts to do what is accomplished when the energy required is all in the form of radiant energy. There is still the possibility that a combination of both forms of energy is involved when $Q_{10}>1$, where q′ parts of q are supplied by radiations (increase in electronic frequencies) and $q-q'$ of the energy is supplied by molecular impacts. This brings the discussion to a point where a physiologist can not carry it further to any advantage and where the interested reader would more profitably consult such works as the reports of the Symposia on Radiation,[1] and Tolman,[2] where one also will find references to the literature. Brief review and fuller citation of the literature by the writer,[3] will also be found in a recent article of which this paper is a brief summary and continuation. Let us rather turn our attention to a few specific cases of physiological processes.

IV. Analysis of Physiological Processes

The phenomenon of photosynthesis in green plants is one that involves the problem stated above and

[1] See *Chemical Reviews*, 1928, vol. v, p. 39; and 1930, vol. vii, pp. 203–258.

[2] R. C. Tolman, "Statistical Mechanics with Applications to Physics and Chemistry," N. Y., 1927, pp. 276–285.

[3] C. D. Snyder, "Quantitative Relations in Biological Processes and the Radiation Hypothesis of Chemical Activation," *Quar. Rev. of Biology*, 1931, Sept. number [in press].

probably the studies of O. Warburg[4] and of O. Warburg and Negelein[5] will be most useful as illustration. In these studies the amounts of carbonic acid assimilated by the action of light on a suspension of the one-celled alga, *Chlorella,* were observed. The light used was of certain selected wave-lengths whose intensities as well as the amounts absorbed by the cells were measured. In the later work the results lead the authors to conclude that photosynthesis in *Chlorella* does not follow directly the law of equivalence, for not one quantum but from 4 to 5 quanta of light energy were found to be absorbed per molecule of carbonic acid assimilated, about 4 quanta for red or yellow light, 5 quanta for blue light.

In the earlier work Warburg reinvestigated what is known as the "Blackman reaction" which refers to the Blackman's observations that the rate of photosynthesis at the higher of the ordinary light intensities is influenced by temperature somewhat to the same extent as are the usual chemical reactions, with temperature coefficients greater than 2; at the least effective intensities of light, however, Q_{10} approaches unity as is the case with many photochemical reactions *in vitro.*

Now it is just this Blackman reaction that illustrates a case where both thermal and photochemical reactions are known to be combined in a living process, and a survey of the results of Warburg are of the greatest interest. In table 3 the present writer has added certain quantities to Warburg's results (which are there reproduced) that can be calculated on the basis of the equations given in part I of this paper, namely the q value from the temperature coefficients, *i.e.,* the "heat of activation," according to the thermodynamic equation (7) but in terms of calories; and finally the ratio of the value of q to the (theoretical) radiant thermal energy per gram molecule of carbonic acid assimilated at the several mean temperatures, and as calculated in calories according to equations (1) and (6)—in short the q/q′ or q/Nhv ratios.

TABLE 3

THE HEAT OF ACTIVATION IN TERMS OF QUANTA FOR PHOTOSYNTHESIS IN CHLORELLA. AFTER THE DATA OF O. WARBURG

Temp. range, deg. C.	5–10	16–25	5.4–10	10–20	20–30	15–25	25–32
Rel. intensity of light	16	16	45	45	45	1.8	1.0
Q_{10}	4.8	2.0	4.3	2.1	1.6	1.06	1.00
q = heat in cal./1000	24.50	11.57	22.70	12.40	8.26	1.11	0
q/Nhv = quanta per molecule CO_2	8.8	4.0	8.2	4.36	2.88	0.384	0

From this table it may be seen at once that for weakest effective intensities of light (I = 1.0) the value of Q_{10} is unity; that is, a rise of temperature from 25° to 32° has no effect on the reaction; q, and accordingly q/Nhv, that is the thermal quanta yield becomes zero. But for the higher intensities Q_{10} increases until it becomes more than 4 for the low temperature ranges and is about 2 for the more usual temperature ranges experienced normally by the active cells. "Heats of activation" thus appear and when put in terms of thermal quanta vary from 2.88 to 8.0 per molecule of CO_2 assimilated. But it is to be recalled that from 4 to 5 quanta of light energy also are absorbed independently of the temperature, in which case it further appears that when the greater intensities of the light are employed and at different temperatures, the total of thermal and photo-radiational quanta involved in the synthesis must vary from 7 to 13. It will be noted further that the thermal quanta, for the more moderate temperature ranges and the higher intensities, are 4.0 and 4.36 respectively. This is also about the yield in thermal quanta that can be calculated from the rate of oxygen absorption by green plants in the dark, as observed by Mattheis (1904) and Yabusoe (1924). That is, carbonic acid production (or the reverse process of carbonic acid assimilation) involves about the same number of thermal quanta as the number of light quanta that are involved in carbonic acid assimilation. Further, the quanta yield in all cases lies between 4 and 10 as was shown must be the case (see table 1) for the vast majority of physiological processes influenced by temperature.

The part of the studies on *Chlorella,* however, that seem to be of greater interest, because less complicated, is that where it was shown that independently of temperature, and when the light intensity is low, the quanta yield is 4 to 5 per molecule of carbonic acid assimilated. This yield is striking when compared to the (thermal) quanta yield of those simpler physiological processes that are influenced in their rates by temperature but not at all by light.

The transmission of nervous excitation is such a process. Dealt with statistically, as was done in the former paper previously referred to on this subject,[3] the temperature coefficients for the more moderate range of temperature vary between 1.90 and 2.38 for frogs' motor nerve. These values give quanta yields,

[4] O. Warburg, *Über die Geschwindigkeit der photochemischen Kohlensäurezererersetzung in lebenden Zellen. Biochem. Zeitschr.* 1919, vol. 100, p. 230.

[5] Warburg und Negelein, *Über die Energieumsatz bei der Kohlensäureassimilation. Zeitschr. f. physikal. Chemie.,* 1922, vol. 106, p. 191.

varying from 3.97 to 5.18 per molecule of whatever substance may be responsible for the transmission of excitation in nerve. In other words, the number of quanta is about the same for a relatively simple physiological process influenced only by heat as it is for an equally simple physiological process that is influenced only by visible light radiations; that is, for carbonic acid assimilation by the green plant when the intensity of the incident rays is weak.

Putting these facts together it seems that the cogency of the problem set forth is established and that there can be no escape from the surmise that the frequency of dark-field radiations in a purely thermal process may play the same rôle that the frequency of visible radiations plays in a purely photochemical process.

This being the case then it would seem that the surmise could be put to the test of experiment by exposing a system, whose reaction is susceptible to thermal changes, to direct infra-red radiations. This indeed has been done by chemists and from their experiments no clear proof has yet been established that absorbed infra-red radiations affect the rate of chemical reaction.[1] However, it would seem that this does not exclude the possibility that with the discovery and application of new methods, the proof may yet be brought forth.

At the same time there is also the possibility that the application of heat to these "thermal systems" brings about radiation among the molecules themselves, that is, the increased force of molecular impacts may produce perturbation among the outer sphere of electrons of atoms, which leads to electron transfers. The atoms themselves thus become sources of radiation, the processes of emission as well as absorption all occurring within the system itself. That this is possible is suggested by the phenomena of chemiluminescence and bioluminescence whereby the application of a variety of external agents, none of which need be primarily radiant energy, the atoms or molecules within the system are brought to a state where they themselves become the source of visible light. If atoms and molecules can thus be made to emit visible radiations it would seem to be all the more probable that they oftener and more easily can be made to emit radiations of lower frequency, that is, infra-red radiations. But such radiations being invisible will be all the less easily demonstrated. Especially must this be the case where the emitted radiations are also absorbed by the same system. Here the chances of detection by a dark-field radiometer obviously become nil.[6]

V. SUMMARY

In the foregoing pages the writer has attempted to point out first, the importance to physiologists of the discovery and application to their problems of a unit of physiological activity to serve as a universal measure of life processes. Second, a survey of the field of excitation and response points to the probability that electron transfers are involved in every case and, therefore, that such a standard of measure, if ever determined, will probably involve terms of radiational units. Third, a brief statement of some of the laws of radiation that seem to be involved is given, together with a sketch of the radiation hypothesis of chemical thermal reaction. Fourth, an analysis of the data of a few physiological processes is then presented, the results of which strongly suggest the possibility that the influence of temperature upon living processes may be due to dark-field radiations quite as much as the photochemical effects in living processes are due to radiation of visible light.

OBITUARY

MEMORIALS

UNDER the leadership of Reginald P. Bolton, a committee has been organized to raise a fund of $25,000 to preserve the home of John James Audubon in New York City. It is planned to move the house to a city park to be used as a public museum.

A FUND is being collected in the Canal Zone for the purchase of an oil painting of General George Washington Goethals, to be hung in the administration building at Balboa Heights. It will be painted by Brigadier General Chester Harding, retired, a former governor of the Canal Zone, who, since leaving the service, has renewed his portrait studies in Paris.

Nature reports that a fête in honor of Henri Moissan was celebrated on October 4, in the cathedral town of Meaux, situated on the banks of the Marne. The delegates were received on October 3 at the Ministry of Foreign Affairs on the Quai d'Orsay, and on the following morning nearly three hundred were taken by special train to Meaux. The ceremonies included the formal presentation to the Communal College (of which Moissan was a pupil from 1864 until 1870) of a plaque on the wall of the entrance hall, and in the afternoon the unveiling, by Mme. Jean Gerard, of a monument in a small square by the side of the town hall. The monument is in the form of

[6] For a full presentation of the physical aspects of the topics dealt with in this paper see vol. 23, *Handbuch der Physik*, 1926, edited by Geiger; especially chapters 5, 6 and 7 by Pringsheim, Noddack, and Franck and Jordan, respectively.

an obelisk, from the upper part of which the features of Moissan emerge from the solid stone, while on the side are sculptured diagrammatic representations of his electric furnace and of the apparatus with the help of which he isolated fluorine, with quotations from his writings. Discourses were delivered under the direction of Professor Behal, representing the minister of public instruction. The first three were by the president of the organizing committee, by the mayor of Meaux, and by the president of the old students' association of the College of Meaux; the others were by M. Lebeau, the assistant and colleague of Moissan, representing the friends and students who had worked in Moissan's laboratory, by Professor Hönigschmid, of Munich, who was a former student of Moissan, on behalf of the foreign delegates and by Professor Behal on behalf of the government.

RECENT DEATHS

DR. SAMUEL RAYNOLDS PARSONS, professor of physics at the University of Arkansas for the last eight years, died on October 10. He was forty-three years of age.

DR. JAMES SIMPSON CHESTER WILLS, metallurgical engineer, at one time adjunct professor of analytical chemistry at Columbia University, died on October 29, aged eighty years.

DR. SAMUEL MATHER, pioneer in the development of the iron mining and steel industries and the Great Lakes shipping fleets, has died at the age of eighty years.

DR. JOHN J. DUNPHY, specialist in pediatrics and instructor of pediatrics at the Harvard Medical School and Tufts Medical School, died on October 13 at the age of thirty-eight years.

MR. JAMES LONG, formerly professor of dairy farming at the Royal Agricultural College in Cirencester, died on October 1. Mr. Long was eighty-five years of age.

MR. J. W. TAYLOR, of Leeds, England, known for his work on conchology, died on September 2 at the age of eighty-seven years.

THE death is announced of Dr. Josef Bayer, director of the division of anthropology and prehistory in the State Museum of Natural History in Vienna, and editor of the journal *Eiszeit*.

PROFESSOR GUIDO HOLZKNECHT, head of the Vienna Roentgen Institute, died on October 30 at the age of sixty years.

SCIENTIFIC EVENTS

APPROPRIATIONS FOR GRANTS-IN-AID BY THE NATIONAL RESEARCH COUNCIL

AT its meeting in October the National Research Council's committee on grants-in-aid made grants for the support of research as follows:

To Thomas B. Brown, professor of physics, George Washington University, cathodofluorescence; E. Hobart Collins, professor of physics, Parsons College, the resonance radiation of mercury.

To H. F. Moore, professor of engineering materials, University of Illinois, the effect of repeated stresses on nickel-chromium steels under high temperatures.

To W. L. Beuschlein, professor of chemical engineering, University of Washington, the hydrogenation of coal in various dispersion media; Richard Bradfield, professor of soils, and W. G. France, professor of chemistry, Ohio State University, size distribution in soil particles; Samuel C. Lind, director of the school of chemistry, University of Minnesota, the chemical reactions produced in gases and other dielectrics by passage of electrical discharge; James W. McBain, professor of chemistry, Stanford University, development of an ultra-centrifuge.

To Harold L. Alling, professor of geology, University of Rochester, the optical properties of feldspars; Julia Gardner, geologist, U. S. Geological Survey, Eocene faunas of northern Mexico; Elbridge C. Jacobs, professor of geology and mineralogy, University of Vermont, installation of a seismograph at the University of Vermont; E. M. Kindle, chief, division of paleontology, Geological Survey of Canada, a bibliographic index of North American Devonian fossils; Asa A. Lee Mathews, assistant professor of geology, Oberlin College, Paleozoic stratigraphy and paleontology of Giles County, Virginia; Joseph T. Singewald, Jr., professor of economic geology, the Johns Hopkins University, petrographic investigations of rock specimens from the Andes of central Peru.

To J. McA. Kater, assistant professor of zoology, Washington State College, the functional significance of mitochondria; Reginald D. Manwell, assistant professor of zoology, Syracuse University, avian malaria; W. D. Salmon, research professor of animal nutrition, Alabama Polytechnic Institute, the relation of vitamin B to carbohydrate metabolism; Bruce Webster, assistant professor of medicine, Tulane University School of Medicine, the nature of a goiter-producing substance found in cabbages.

To Alan A. Boyden, assistant professor of zoology, Rutgers University, serological study of the early development of the chick; E. B. Copeland, research associate in the department of botany, University of California, the Old World species of the fern genus *Trichomanes;* Berwind P. Kaufmann, professor of

botany, University of Alabama, chromosome structure in several plant genera; Harold Kirby, Jr., associate professor of zoology, University of California at Berkeley, protozoa of termites; C. L. Turner, professor of zoology, Northwestern University, fishes of the Mexican plateau.

To J. E. Coover, professor of psychology, Stanford University, analysis of expert performance in typing; Warren K. Moorehead, director of the department of archeology, Phillips Academy (Andover), classification of stone-cutting tools of the American Indians of the United States and Canada; S. L. Pressey, professor of educational psychology, and L. C. Pressey, assistant professor of educational psychology, Ohio State University, emotional attitudes and interests among certain tribes of American Indians; Ruth Sawtell Wallis, assistant professor of sociology, Hamline University, cranial types of western Europe.

VERNON KELLOGG,
Secretary

THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ACCORDING to the *U. S. Daily*, facilities of the Langley Memorial Laboratory of the National Advisory Committee for Aeronautics were made available to members of the nation's aircraft industry on October 22 when the committee at its regular annual meeting passed a resolution favoring such action.

Use of the laboratory for test purposes will be permitted, providing the individual pays the expense, the resolution provided. This action was taken, it was explained orally at committee headquarters, in order that test projects not of general interest to the industry, yet capable of being carried out only at the Langley laboratory, might be conducted for the benefit of individual manufacturers.

Results of such experimental and test work will be turned over to the person requesting the test, it was agreed, but in the discretion of the committee may also be published for general distribution.

Rear Admiral William A. Moffett, chief of the bureau of aeronautics, Department of the Navy, extended the committee an invitation to inspect the new naval airship *Akron*. Considerable research work on airships was conducted by the National Advisory Committee for Aeronautics at Langley Field in conjunction with building of this dirigible.

The committee also adopted a testimonial resolution on the death of Dr. Samuel W. Stratton, late president of Massachusetts Institute of Technology, former director of the Bureau of Standards, one of the three organizers of the committee and a member of the research group since its formation.

Dr. Joseph S. Ames was reelected as chairman and Rear Admiral David W. Taylor (retired) as vice-chairman. The executive board which was elected consists of Dr. Ames, Admiral Taylor, Dr. Charles G. Abbot, Dr. George K. Burgess, Major General James E. Fechet, Mr. William P. MacCracken, Jr., Brigadier General Henry C. Pratt, Admiral Moffett, Captain Arthur B. Cook, U. S. N., Mr. Edward P. Warner and Mr. Orville Wright.

THE DOHME FOUNDATION AND NATIONAL FELLOWSHIPS AT THE JOHNS HOPKINS UNIVERSITY

IN the first lecture of the 1931–32 series under the Dohme Foundation, given at the Johns Hopkins University on October 23, Dr. Leo Hendrik Baekeland, honorary professor of chemical engineering at Columbia University, addressed the faculty and students of the department of chemistry. Under the title, "My Mistakes," the lecture dealt with the fortunate accidents which have contributed to Dr. Baekeland's long and successful career in chemical research and industry, describing from the speaker's personal experience the adjustments that must be made by a man who carries the spirit of pure research into the industrial field.

The lecture was followed by a dinner given in honor of Dr. Baekeland by the students under the national fellowship plan, in connection with which the Dohme Foundation lectures are conducted. This furnished the first occasion of the academic year for a formal gathering of these students, who now number thirty-one. The new incumbents of national fellowships are: Philip G. Ackerman, from Oregon State Agricultural College, on the American Can Company fellowship for Oregon; C. Gerald Albert, from Yale University, the Mary Carroll Garvan memorial fellowship for Connecticut; R. Keith Blakely, from the University of New Mexico, the Chemical Foundation fellowship for New Mexico; Kenneth W. Brighton, from the University of Utah, American Can Company fellowship for Utah; Harold G. Burman, from Dakota Wesleyan University, Chemical Foundation fellowship for South Dakota; Lawton A. Burrows, from Drury College, William R. Warner and Company fellowship for Missouri; Clayton W. Ferry, from the University of North Dakota, John M. Hancock fellowship for North Dakota; William P. Hall, from Occidental College, American Can Company fellowship for California; Arnold L. Lippert, from the University of Illinois, Central Scientific Company fellowship for Illinois; Robert J. Myers, from Creighton University, Cudahy Packing Company fellowship for Nebraska; James L. Nauman, from Cornell College, G. A. Pfeiffer Company fellowship for Iowa; Charles C. Rainey, from Emory University, Coca-Cola Company fellowship for Georgia.

Subsequent lecturers for this year under the Dohme

Foundation are scheduled as follows: Dr. C. F. Kettering, of the General Motors Corporation, Detroit, Michigan; Dr. Julius Stieglitz, of the University of Chicago; Dr. James F. Norris, of the Massachusetts Institute of Technology; Dr. Gilbert N. Lewis, of the University of California; Dr. Irving Langmuir, of the General Electric Company, Schenectady, N. Y.; Professor Alfred Stock, of the Technische Hochschule, Chemisches Institut, Karlsruhe, Germany, and Professor Simon, of the University of Breslau.

THE LOWELL LECTURES

THE Lowell Institute program of free public lectures for 1931–32, the ninety-second year of the Boston foundation, is announced by President A. Lawrence Lowell, trustee, and Professor W. H. Lawrence, curator. The lectures began on October 26, and will end during the latter part of March.

According to a statement in the Boston *Evening Transcript*, there are nine courses scheduled, a total of sixty-one lectures, or about the usual number. The opening date is nearly four weeks later than the opening of the season of last year and two weeks later than the season of two years ago. Five of the lecturers are coming from abroad and two are from Harvard University.

The first course, to be given on Mondays and Thursdays at five o'clock in the afternoon, began on Monday October 26. It is by Dr. F. van Bemmelen, formerly professor of zoology at the University of Groningen, the Netherlands, on "Color and Shape in the Living World." The topics are as follows:

1. The Development of the Color-Pattern and the Veins on the Wings of Butterflies.
2. The Relations of Skin-Design between Caterpillar, Pupa and Butterfly.
3. A Natural Explanation of the Origin of Mimicry in Butterflies.
4. The General Plan of Skin-Design in Mammals.
5. The Phenomenon of Second-Self in Man, Explained by Heredity of Family Likeness.
6. The Heredity of Curly Hair in Man, Studied by Means of Portraits.
7. The Ancestral Table and the Parentela: the Two Principal Methods for the Study of Human Family Descent.
8. Sexual and Asexual Propagation, in Their Relation to the Cell Theory.

Second on the list is a course of six lectures with illustrations by Dr. W. de Sitter, director of the observatory and professor of astronomy at the University of Leiden, on "The Development of our Insight into the Structure of the Universe." This course will be delivered on Tuesdays, Fridays and Saturdays at 8 P. M., and began on Tuesday, November 3. The topics are as follows:

1. Aims and Methods of Scientific Research. The Ancients. Ptolemy and Copernicus.
2. The Birth of Modern Astronomy: Kepler, Galileo, Newton. The Eighteenth Century.
3. The Beginning of Sidereal Astronomy: William Herschel and His Successors.
4. Further Observational Advances. The Survey of the "Local System": Lifework of J. C. Kapteyn.
5. Photography and Spectroscopy. The Great Telescopes. Extragalactic Systems.
6. Relativity and Modern Theories of the Universe.

SCIENTIFIC NOTES AND NEWS

THE Nobel Prize in medicine and physiology for 1931 has been awarded to Professor Otto Warburg, head of the department of biology of the Kaiser Wilhelm Institute, for his work on cellular metabolism.

THE Perkin Medal Committee of the American section of the Society of Chemical Industry has awarded the Perkin Medal for 1932 to Dr. Charles F. Burgess, of the Burgess Laboratories, Madison, Wisconsin, for his achievements in the field of electrochemistry. The medal will be presented to Dr. Burgess at a meeting in New York on January 8.

MASANI NAGATA, the Japanese melon farm foreman and amateur astronomer, has been awarded the Donohoe Comet Medal by the Astronomical Society of the Pacific for his discovery last July.

DR. WALDEMAR C. BRÖGGER, professor emeritus of geology at the University of Oslo, Norway, will celebrate his eightieth birthday on November 10.

DR. H. FOSTER BAIN, who resigned recently as secretary of the American Institute of Mining and Metallurgical Engineers to become managing director of the Copper and Brass Research Corporation, received a gold watch from the officers and directors of the institute at the monthly dinner and meeting of the New York section at the Hotel Commodore on October 28. The speakers included Mr. J. V. W. Reynders and Mr. E. DeGolyer, past presidents of the institute, Mr. A. B. Parsons, the incoming secretary, and Dr. Bain.

AFTER a letter from Lord Beauchamp to the University of London Graduates' Association announcing his resignation as chancellor of the university had been read at a meeting of the council, it was resolved unanimously to invite Lord Moynihan, president of the Royal College of Surgeons of England, and a graduate of the university, to accept the association's nomination for the office of chancellor.

DR. F. N. GUILD, for thirty-four years professor of mineralogy at the University of Arizona, has retired from active work and has been made professor emeritus of optical mineralogy.

A DIVISION of graduate study, coordinate with the other major divisions of the institution, has been established at the Kansas State College of Agriculture and Applied Science. Dr. James E. Ackert, professor of zoology and since 1923 chairman of the graduate council, has been made dean of the new division.

DR. HORACE B. ENGLISH, formerly professor of psychology at Antioch College, has been appointed professor of psychology at the Ohio State University.

MISS KATHERINE HARING, of New Haven, Connecticut, a graduate of the class of '29 at Mount Holyoke College, has become the recipient of the Loomis fellowship of $1,500 in chemistry at Yale University. Miss Haring is the first woman to receive this fellowship, which is made on the basis of the results of two years of graduate work.

THE Mellon Institute of Industrial Research announces the foundation of an industrial fellowship by the Green Bag Cement Company of Pittsburgh, a subsidiary of the Davison Coke and Iron Company. The investigational work of this fellowship, which will be carried on by Mr. Raymond C. Briant, will be concerned with studies of the chemical and physical properties of Portland cement and with the development of certain new cement products.

DR. WALTER B. CARVER, professor of mathematics at Cornell University, will become editor-in-chief of the *American Mathematical Monthly*, beginning in January, 1932.

DR. CLARENCE O. CHENEY, formerly superintendent of the Hudson River State Hospital at Poughkeepsie, N. Y., has been appointed director of the New York State Psychiatric Institute. He succeeds Dr. George H. Kirby, who recently retired.

DR. GUY R. STEWART has been appointed senior forest ecologist with the U. S. Forest Service, and is attached to the Northeastern Forest Experiment Station at Amherst, Massachusetts. He is project leader on an ecological study of the factors associated with the success or failure of forest plantations in the northeastern United States.

DR. GEORGE GRANT MACCURDY, director of the American School of Prehistoric Research, represented Yale University at the celebration of the fiftieth anniversary of the opening of the Natural History Museum Building, held in the museum, South Kensington, London, on September 29 and 30, 1931.

DR. JOHN RICE BALL, associate professor of geology and paleontology in Northwestern University, is spending a sabbatical year abroad. He will devote a large part of his time to a study of the Silurian formations and to the museums which contain considerable collections of Silurian fossils.

DR. WORTH H. RODEBUSH, professor of physical chemistry at the University of Illinois, recently returned from a summer trip through Europe. Most of his time was devoted to visiting universities in Germany and other countries.

DR. MATILDA MOLDENHAUER BROOKS, research associate in biology at the University of California, has returned from the South Seas, where she spent several months on scientific research under a grant from the Bache fund of the National Academy of Sciences.

IN announcing in SCIENCE for October 16 the appointment of Dr. Louis B. Slichter, of the California Institute of Technology, as associate professor at the Massachusetts Institute of Technology, it should have been said that it was of geophysics in the department of geology.

ON October 18, at the Auditorium Hotel, Chicago, Dr. E. H. Volwiler, chief chemist of the Abbott Laboratories and former chairman of the Chicago section of the American Chemical Society, was guest of honor and speaker of the evening at the regular monthly dinner meeting of the Chemistry and Physics Society of De Paul University. Dr. Volwiler selected for his topic "Chemistry and its Relation to Medicine."

DR. E. D. ADRIAN, fellow of Trinity College, Cambridge, and Foulerton research professor of the Royal Society, will deliver the second Harvey Society lecture at the New York Academy of Medicine, on November 19. His subject will be "The Messages in Sensory Nerve Fibers."

THE twelfth Pasteur lecture of the Institute of Medicine of Chicago will be given on November 27, at the City Club, Chicago, by Dr. Rufus I. Cole, director of the Hospital of the Rockefeller Institute for Medical Research. Dr. Cole will speak on "The Nature of Pneumonia."

DR. WILLEM DE SITTER, director of the Leiden Observatory, gave a series of three lectures at the University of Pennsylvania, on October 19, 20 and 21, on "The Extent of the Universe." These lectures were made possible by the Tobias Wagner Fund, devoted to lectures on astronomy. Dr. de Sitter delivered an address on "The Origin of the Planetary System" at a joint meeting of the Washington Academy of Sciences and the Society of the Sigma Xi in Washington on October 26.

THE Mineralogical Society of Southern California was formed recently and held its first meeting on June 23 at the Pasadena Library, with an attendance of 175. The following were elected to hold office until June, 1932: *President,* Mr. John A. Renshaw; *vice-president,* Mr. W. S. Morton; *secretary,* Mr. Edwin Van Amringe; *treasurer,* Miss Helen Fowler.

A SYMPOSIUM on poliomyelitis, sponsored by the New York state department of health and a group of pediatricians from New York State and adjacent territory in Canada, will be held in the auditorium of the College of Pharmacy, in Albany, on Thursday, November 12, at 10:00 A. M. The program, which was arranged by Dr. H. L. K. Shaw, program chairman for the pediatricians, and Dr. Thomas Parran, Jr., state commissioner of health, will include addresses by a number of experts in poliomyelitis control and research. Among the speakers are Commissioner Parran, Dr. Lloyd W. Aycock, director, Harvard Infantile Paralysis Commission; Dr. George Draper, professor of clinical medicine, Columbia University; Dr. William H. Park, director, bureau of laboratories, New York City department of health; Professor J. G. FitzGerald, director, Connaught Laboratories, University of Toronto, and Dr. Simon Flexner, director, the Rockefeller Institute for Medical Research. In view of the recent epidemic of poliomyelitis and the wide-spread interest it aroused, it is believed that this symposium will be of special value in summarizing present knowledge of the various phases of the subject. The district consultants in poliomyelitis, health officers and physicians are cordially invited to attend.

SECRETARY OF AGRICULTURE ARTHUR M. HYDE was the principal speaker and guest of honor at the opening of the Florida Citrus Products Laboratory of the Bureau of Chemistry and Soils at Winter Haven on October 23. The buildings, grounds and certain other facilities required for the station were furnished by the citrus interests of Florida, in accordance with a proviso in the appropriation act which provided federal funds for the laboratory's work. The laboratory was dedicated at a luncheon given by the city of Winter Haven and its chamber of commerce. Representative H. J. Drane, of the first congressional district of Florida, presided. Following the address by Secretary Hyde, addresses were made by Dr. Henry G. Knight, chief of the U. S. Bureau of Chemistry and Soils; Dr. W. W. Skinner, assistant chief of the chemical and technological research unit of the bureau, and Dr. F. C. Blanck, chief of the food research division of the bureau. The department officials explained the functions of the laboratory and the relation of the research work of the department to the citrus industry.

THE eleventh annual meeting of the highway research board, National Research Council, will be held on December 10 and 11, in Washington, D. C. The meetings will be in the auditorium of the National Academy of Sciences. The sessions will be devoted to discussions of reports of research activities in relation to highway finance, transportation, design, materials and construction, maintenance and traffic.

AN International Federation of Societies of Tropical Medicine and Hygiene has been organized in Paris. The president is Professor C. Achard, and the secretary general is Dr. M. Zeitoun. This federation is intended to include the societies of tropical medicine and hygiene throughout the world and is for the purpose of collaboration and coordination of study and research in these subjects. Colonel Charles F. Craig, professor of tropical medicine and director of the department of tropical medicine at the School of Medicine, at Tulane University, of Louisiana, has been elected a member of the international council of the federation and secretary general of the commission for scientific study of tropical diseases. The American Society of Tropical Medicine has been invited to become a member society of the international federation.

IN recognition of its work in forest research, the school of forestry of the University of Idaho has been elected to membership in the International Union of Forest Research Organizations. Notification came from Dr. Sven Petrini, the secretary-general at Experimentalfaltet, Sweden. The International Union was established in 1929 and has as its aim the promotion of international cooperation in the various branches of forest research. It comprises more than 80 forest research organizations in 30 countries. Seven other institutions in the United States in addition to the Idaho School of Forestry now belong to the union.

COLBY COLLEGE has received $250,000 under the will of Professor Julian D. Taylor under the condition that the college raise the balance of a $3,000,000 fund.

DAMAGES of $390,000 have been awarded the trustees of Boston University for the taking of about 130,000 feet of land along the Charles River, Bay State Road and Chilmark Street, Boston, for the purpose of building a state highway along the river bank. A jury in the Suffolk Superior Court made the award.

THE committee on drug addiction of the National Research Council has granted the sum of $14,220 for research work to be conducted at the University of Michigan during the present academic year. This is an increase of $4,020 over the amount allocated for

1930-31. The work is to be carried on as previously under the direction of Dr. C. W. Edmunds and Dr. Nathan B. Eddy.

THE government of Manitoba has awarded a contract for the erection of the new science building of the University of Manitoba. A Winnipeg firm of contractors is to construct the building at a tendered price of $536,197 for all stone construction.

THE new Harvard astronomical observing station will be built on the highest point between Mount Wachusett and the sea, on Oak Ridge, Harvard, Massachusetts, twenty-seven miles northwest of Cambridge. The land was given to the university by Mr. and Mrs. Alfred C. Fuller, of Belmont. Construction will begin early in the spring, according to an announcement by Dr. Harlow Shapley, director of the observatory. At this station the new 60-inch reflector telescope, the largest astronomical instrument in the East, will be the most important part of the equipment. Five or six of the observatory's other photographic telescopes will also be moved from Cambridge to the new station.

A MODERN dormitory for animals has been completed at Wellesley College. In the new zoology unit there is a fully equipped vivarium, containing airy rooms for the small animals and capacious aquariums and frog and turtle tanks. The animal rooms are separate, insuring complete seclusion. From each room a trap door leads to an outside runway, and these inclosures are separated from each other by concrete walls that extend eight feet underground to prevent burrowing. Each room has two doors, one of glass, the other of wire. The floors are of tile and the walls of concrete, to insure sanitary living conditions. There is a small kitchen where the animals' food is prepared. The department has its own greenhouse in which to raise fish foods and plants for the lice used in experiments. Everything has been done to assure the comfort of the animals while they are awaiting experimentation. The vivarium has eight small aquariums, open on three sides, and two large ones, open on all four sides. For the fish that need fresh water, lake water has been pumped from Lake Waban. Salt water has been stored in the basement for the ocean fish.

ACCORDING to a press report, Dr. George Gaylord Simpson, head of the Scarritt Patagonian expedition, returned on October 28, on the Munson liner, *American Legion,* after an absence of more than a year spent studying fossil mammals in the lower region of Patagonia. Although some of the specimens had been sent up previously for mounting at the American Museum of Natural History, Dr. Simpson said that others would be forwarded later by the government of Argentina. Dr. Simpson left New York in August, 1930, but only seven months were devoted to collecting specimens, as he had spent several months lecturing at the museum in Buenos Aires. Dr. Simpson was accompanied on the expedition by Mr. Coleman S. Williams of the museum staff, who returned to New York a few weeks ago. The area traversed by the expedition included 5,000 square miles inland from the base camp at Commodoro Rivadavia, which was reached by oil tanker from Buenos Aires.

AN expedition in the interest of fifteen small museums, of which Captain Harry Carpelan is in command, sailed from New York on October 1. The expedition is to cost more than $330,000 and is to be financed by a group of wealthy persons from various parts of the United States. The cruise will be made in a four-masted schooner with auxiliary motors. The itinerary will include Porto Rico, Haiti, the Galapagos, the Marquesas, Samoa, Society and other Pacific islands, Australia, New Caledonia, the New Hebrides, Dutch New Guinea, Borneo, Java, Sumatra, Siam, French Indo-China and the Hawaiian Islands. The voyage will end in Los Angeles in 1933. Those to make the trip, numbering about thirty-five, include several anthropologists, an ornithologist, an ichthyologist, an oceanographer, a zoologist, a sculptor, several painters, photographers and sound-motion picture operators. One representative will be sent by each of the museums to participate.

EXPLORATION work by Mr. A. F. Moore, of the Astrophysical Observatory, Smithsonian Institution, who is in South West Africa studying sky conditions, has been hindered by many obstacles. The *U. S. Daily* states that Mr. Moore spent about two weeks on the summit of Lord Hill, about 60 miles east of Keetmanshop, South West Africa. Employing instruments for measuring atmospheric humidity and intensity of solar radiation, he has made daily observations, making notes also of the visible appearance of the sky. Great difficulties have been encountered. Mountains there are inhabited only at their bases, where natives live. In their upper regions they are trackless and nearly inaccessible, in some cases rising almost perpendicular, making ascent almost impossible. The observatory's permanent observation peak in that country is Mount Brukkaros. Mr. Moore plans to record observation conditions on other peaks, compare them to those on Brukkaros, with a possibility of finding a better observation station. On Lord Hill, Mr. Moore finds that the haze and dust seldom reaches the summit, and as a result, observations may be made when they would be impossible from a lower elevation. Lord Hill is more than 7,000 feet high. After he has worked in the Lord Hill district, Mr. Moore will go north to Windhock, visiting Mounts Brandberg and Gansberg on his return to Brukkaros.

DISCUSSION

A FORGOTTEN CONTRIBUTION TO NUTRITION BY MAGENDIE

McCAY[1] has called attention to the hitherto little recognized feeding experiments of Magendie in 1816, in which that noted physiologist tried to demonstrate the importance of nitrogenous foods in the diet. The criticism applied to some of Magendie's work has been its lack of completeness. It is of interest, therefore, to note that the distinguished teacher of Claude Bernard performed further nutrition investigations that supplement and extend the knowledge derived from his early failures to maintain dogs on rations of isolated materials. These additional and practically forgotten experiments in some respects exceed in value the later and more celebrated contributions of the gelatine commission, of which Magendie was chairman. Although, strangely enough, this work is not quoted in the gelatine report it is described in all but the first editions of the "Précis Elémentaire de Physiologie." The experiments are also discussed by Londe[2] and Johannes Müller.[3] The story may be retold as it could have been read nearly a hundred years ago in the American edition of Magendie's text-book.[4]

> Since the publication of these facts (the experiments of 1816), in the first edition of this work, I have observed others not less important, which show how limited our knowledge still is on the subject of nutrition.
>
> A dog was allowed to eat pure wheaten bread and drink common water at will. He died within fifty days, with all the signs of marasmus in the highest degree.
>
> Another dog ate exclusively *military* or *munition* bread; his health continued perfectly good.
>
> Rabbits or Guinea-pigs fed with a single substance, as wheat, barley, oats, cabbage, carrots, etc., will die, apparently from inanition, within a fortnight, and sometimes much sooner. But if the same substances be given together, or after short intervals, the animals live, and do well.
>
> I fed an ass on dry rice, and afterward boiled it in water, because he refused the first; the animal lived only fifteen days. The last days he constantly refused to eat the rice. A cock was fed on boiled rice for several months, and preserved its health.
>
> Dogs fed exclusively with cheese, and others with hard eggs, lived for a long time, but became weak and emaciated; lost their hair, showing imperfect nutrition. . . . The most general and important consequence deducible from these facts, and which ought to be followed up and examined, is, that diversity and multiplicity of aliments is a very important hygienic rule. This is indicated by our instincts, and the variations that the seasons bring in the nature and kind of aliments.

While the precise duplication of Magendie's experiments might prove difficult and while failure to eat in some instances masked the effects produced by the diets, yet in general, the qualitative results are such as might be expected from the standpoint of our modern knowledge. Magendie's interpretations are particularly skilful. The author indicates a rational solution to the practical problems of nutrition and yet recognizes that the field is just being opened. From the historical aspect we may credit Magendie as being one of the first physiologists to use rodents for nutritional investigations. The plan of the experiments described shows that he must have realized that the nutritive requirements of different species may vary. Finally, in view of our present data on the phenomena of dietary deficiencies in animals, his observation, that prolonged consumption of poor diets might result in loss of fur and in general emaciation, is peculiarly significant. One is almost tempted to say that Magendie observed, thereby, some of the signs of vitamin G deficiency in his dogs fed on eggs or cheese alone.

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WESTERN RESERVE UNIVERSITY,

A PROPOSED CLASSIFICATION OF DISEASE TRANSMISSIONS BY ARTHROPODS

THE diseases which are transmitted by insects and other arthropods often are classified according to the causative organism, and sometimes according to the transmitting agent. Each classification serves definite purposes. I should like to propose a classification based upon the type of transmission which occurs, not with the idea of attempting to supplant either of the systems of classification already established, but rather with the hope that this one will supplement and probably clarify the others.

The nearest approach to such a classification is the well established use of the terms "biological" and "mechanical" in connection with transmission by arthropods. These words have served a purpose, but they are inadequate for clearness. It is also true that authors are not in agreement as to their exact meanings. The transmission of malarias by mosquitoes is certainly biological. The transmission of anthrax and surra in cattle by blood-sucking flies is mechanical. In many cases the classification of the transmission is not so easily made, and authors classify them in one group or another depending upon their conception mainly of what constitutes a

[1] C. M. McCay, "Was Magendie the First Student of Vitamins?" SCIENCE, 71: 315, 1930.

[2] C. Londe, "Note sur les Alimens," *Arch. gén. de Méd.*, 10: 51–66, 1826.

[3] J. Müller, "Elements of Physiology," transl. by W. Baly, American ed. by J. Bell, Philadelphia, p. 333, 1843.

[4] F. Magendie, "An Elementary Treatise on Human Physiology," transl. by J. Revere, New York, p. 485, 1845.

biological transmission. Unfortunately, some writers have interpreted biological to mean cyclical, that is, that the parasite concerned undergoes morphological change in the transmitting arthropod. It seems obvious, however, that at least two biological events may occur in the life of a parasite during its sojourn in the invertebrate host. It may multiply, or it may undergo cyclical change. Other changes are conceivable, but as yet not demonstrated. The four combinations which may be made of these two biological events are given below, together with the names being

	Multiplication of organism in vector	No multiplication of organism in vector
Cyclical change of organism in vector	I. Cyclo-propagative Example: Malaria by mosquitoes	II. Cyclo-developmental Example: Filaria by mosquitoes
No cyclical change of organism in vector	III. Propagative Typhus by lice	IV. Mechanical Typhoid by flies

proposed for the type of transmission represented by the combination.

It will be noted that the older term, biological, can still be retained as a collective term for types I, II and III in contrast to type IV, for which I have retained the old term, mechanical. The classification proposed is, then:

Diseases Classified According to Type of Transmission

A. Biological

I. Cyclo-propagative—the organisms undergo cyclical change and multiply.

II. Cyclo-developmental—the organisms undergo cyclical change but do not multiply.

III. Propagative—the organisms undergo no cyclical change, but they multiply.

B. IV. Mechanical—the organisms undergo neither cyclical change nor multiplication.

It is, of course, difficult to classify all arthropod-borne diseases on such a scheme. The transmission of relapsing fever by ticks is very probably propagative, but since it is believed by some authors that the spirochaete undergoes a change in morphology in the tick, it is possible that this transmission may be cyclo-propagative. Also, some diseases may fall into two (or possibly more) classifications. The transmission of bubonic plague may be propagative, since we know that the causative organism can multiply in the foregut of the flea, and also possibly mechanical, by the direct passage of the organisms in the feces of a flea recently fed on an infected rat. However, it is believed that these cases do not lessen the value of the classification.

When the diseases of man are tabulated according to this scheme, certain facts stand out prominently which were previously obscure or unobserved. For example, it is found that a relatively small group of diseases is transmitted mechanically by arthropods. Also, when one looks for those diseases of greatest importance he finds them in groups I and III. The one characteristic, then, which they have in common is their ability to multiply within their arthropod hosts. The possible exception to this statement is the case of filariasis. However, the difficulty which this disease has in spreading is well known, and must certainly be attributed largely to the fact that the filarial organism does not multiply in its vector. The fact that the most important arthropod-borne diseases of man have one thing in common suggests that more emphasis should be placed upon investigating this common characteristic; that is, toward discovering what factors are concerned in determining whether a parasite can or can not multiply in its invertebrate host.

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GLAUCONITE AND FORAMINIFERAL SHELLS

IN the issue of SCIENCE for July 3d, A. L. Dryden, Jr., makes some statements relative to the occurrence of glauconite in fossil foraminiferal shells. The writer has been studying the mechanics of concretion development in fossil-bearing concretions from the Cook Mountain (Eocene) formation of Brazos County, Texas. This formation carries large amounts of glauconite, but the observations recorded below were made wholly on the glauconite found within the concretions. The figures are from counts made on

TABLE I

Type of occurrence	Number
Irregular, free, unpolished glauconite grains	126
Thoroughly rounded and polished, free glauconite grains	1911
Empty foraminiferal shells	21
Foraminiferal shells packed with glauconite	189
Foraminiferal shells packed with a mixture of glauconite and other mineral matter	57

TABLE II

Ratio of total free glauconite grains to total grains occupying foraminiferal shells	8.28 to 1
Ratio of foraminiferal shells packed with glauconite to shells packed with a mixture of glauconite and other mineral matter	3.33 to 1
Ratio of total packed foraminiferal shells to empty shells	11.10 to 1

petrographic thin sections cut from parts of 14 concretions. The grains recorded as "polished" are either circular or elliptical in section. If they were originally formed in the interiors of the foraminiferal shells the shells had been entirely removed and the grains rounded prior to their inclusion within the concretions.

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PEAT UNDER A DELAWARE BEACH

THE article by Dr. Richards on the occurrence of sod under the New Jersey beaches, which appeared in SCIENCE for June 19, interested me very much. Similar material was found in 1911 on the beach at Rehoboth, Del. This was reported and figured in an article published in 1913.[1]

The material, a mass of peat several feet long, was exposed twice during the summer, after severe storms. It was embedded in the sand and appeared to continue landward as it disappeared under the sloping beach. A piece approximately a foot and a half in diameter was broken from the mass and is now in the Museum of the Department of Botany, Wellesley College. Other deposits, one described by a fisherman as "turf with stumps in it," were reported to have been exposed during winter storms.

The occurrence of peat in this situation was interpreted at that time as the remains of a marsh flora, developed from a lagoon formed by an old fringing bar. As the bar was pushed inland the sand overwhelmed the marsh and continued retreat of the shore line again exposed the buried vegetation.

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SPECIAL CORRESPONDENCE

A FLORA OF MEXICO

OUR knowledge of the flora of Mexico is scattered through a multitude of systematic papers and a relatively small number of local floras, with only very few general works. The fundamental work for the study of the flora as a whole, Hemsley's four volumes of "Botany" (1879–88) in Salvin and Godman's great "Biologia Centrali-Americana," enumerates 12,233 species of vascular plants growing in the region from Mexico to Panama, with the citation of synonyms and specimens examined (the latter almost confined to the material in the Kew Herbarium). There are no keys, no vernacular names and no account of uses, and the botanist who does not have access to a large botanical library can derive little profit from it. Paul C. Standley's "Trees and Shrubs of Mexico" (1920–26) covers the woody plants very satisfactorily, giving keys, brief descriptions, synonymy and range, but its greatest value, perhaps, lies in the condensed accounts of uses and lists of vernacular names which the author has brought together under each species. The approximately 5,700 species included in this work represents perhaps half the known flora. The floras of several of the islands on the west coast have been published by Sereno Watson, E. L. Greene, J. N. Rose (partly in collaboration with George Vasey), Alice Eastwood and Mrs. R. S. Ferris. L. A. M. Riley's "Contribution to the flora of Sinaloa" (1923–24) was left incomplete at the death of the author and covers only the Polypetalae. A flora of the same state, the descriptive part of which, containing various new species, is unfortunately printed on unnumbered pages so as to be almost impossible to cite, is in process of publication by J. G. Ortega in the "Boletín de Procultura Regional" of the Sociedad Cooperativa Limitada of Mazatlán. Millspaugh's "Plantae Yucatanae," mostly written in collaboration with Mrs. Agnes Chase, was suspended nearly thirty years ago, after only five families had been covered. This gap has been filled by Standley's "Flora of Yucatan" (1930), the only complete flora of any Mexican state. The very interesting flora of the peninsula of Lower California, an area not included in Hemsley's "Botany," has been pretty thoroughly covered by T. S. Brandegee, especially as to the "Cape Region," and additional lists of value have been published by E. A. Goldman and I. M. Johnston.

The participation of United States botanists in the investigation of the flora below the present northern boundary of Mexico practically began with Asa Gray's papers on Charles Wright's second Texan and New Mexican collection (1853) and on Thurber's New Mexican and Sonoran collections (1854), and Torrey's "Botany of the [Mexican] Boundary" (1859), in which Gray collaborated. Into these works occasional species collected within the present limits of Mexico were introduced. Gray's papers on Xantus' plants from Lower California and L. C. Ervendberg's from Wartenberg, near Tantoyuca (both in 1861), were the first papers devoted entirely to Mexican plants published in this country. After a gap of fifteen years, Sereno Watson's two papers (1876) on

[1] Laetitia M. Snow, "Progressive and retrogressive changes in the plant associations of the Delaware coast," *Bot. Gaz.*, 55 (1): 45–55, fig. 6, 1913.

the flora of Guadalupe Island, based on Palmer's 1875 collection, began the long series of publications from the Gray Herbarium devoted to the results of the Mexican explorations of Palmer, Pringle and other collectors. The paper by George Vasey and J. N. Rose (1889) on Palmer's plants of 1889 from Lower California initiated the activity of the U. S. National Herbarium in the description of the Mexican flora, in the investigation of which Dr. Edward Palmer, who collected for the United States Department of Agriculture, played a part equalled only by Pringle.

It will be noticed that with the exception of two floras, both of which are incomplete, all the publications above mentioned on the geographical botany of Mexico since the time of Hemsley have been produced by botanists of the United States. An explanation of this, of course, is to be found in the relative accessibility of Mexico as a collecting field to the botanists of its northern neighbor. Of the trinity of modern botanical collectors in Mexico whose specimens have been widely distributed—Palmer, Pringle and Purpus—the two first were citizens of the United States and the third collected principally for T. S. Brandegee. The very extensive Mexican collections of J. N. Rose are, of course, found principally in the U. S. National Herbarium. The largest collection ever made in a relatively small area in Mexico, that of Brother G. Arsène and his associates from the regions of Michoacán and Puebla, is most completely represented in the same herbarium.

The case is quite otherwise as regards our knowledge of the useful and medicinal plants of Mexico and their vernacular names. These matters appear to have received no attention from Pringle, but were among the primary objects of Palmer's work in Mexico on behalf of the Department of Agriculture. Opportunities for acquiring information on such subjects, however, are of course much greater to residents of a country than to those who visit it only on relatively brief collecting trips. We find, consequently, that most of the important contributions have been made by botanists resident in Mexico. The principal works on medicinal plants are L. Flores' "Manual terapéutico de plantas mexicanas" (1909), B. Cuevas' "Plantas medicinales de Yucatán . . ." (1913), and L. Suc's "Les plantes medicinales du Mexique" (1912), the last a compilation from the University of Toulouse. For useful plants in general, the outstanding works are J. N. Rose's "Notes on useful plants of Mexico" (1899), which was based principally on the author's own observations and those of Palmer, and M. Martínez' "Las plantas mas utiles que existen en la república mexicana" (1928). For vernacular names, the principal sources are J. Ramírez and G. V. Alcocer's "Sinonimia vulgar y científica de las plantas mexicanas" (1902), and M. Martínez' "Catálogo alfabético de nombres vulgares y científicos de plantas que existen en Mexico" (1923–). The latter, not yet completed, is similar in plan to Ramírez and Alcocer's "Sinonimia," but contains many additional names. Nicolas Leon's "Biblioteca botánico-mexicana" (1895), a work of 372 pages, contains an alphabetical list, with publications, of 805 authors who have written on the flora of Mexico, with sketches of botanical explorations and collectors. José Ramírez' "La vegetatión de Mexico . . ." (1899) discusses the phytogeographical divisions of Mexico proposed by various authors, and in addition contains a useful hundred-page list of altitudes of localities. The only attempt at a list of Mexican plants since Hemsley, M. Urbina's "Catálogo de plantas mexicanas (fanerógamos)" (1897), based on the collections of the Museo Nacional, contains only about 3,000 species, and represents less than a third of the known flora.

The task of bringing into one work the information scattered through so many publications is a gigantic one. It has been undertaken by Professor Cassiano Conzatti, of Oaxaca de Juarez, known to botanists of the United States for many years as the collector of excellent specimens of Mexican plants. More than thirty years ago Professor Conzatti, in collaboration with L. C. Smith, a clergyman in Oaxaca, published Parts 2 and 3 of a "Flora sinóptica mexicana" (1895–7). A second edition of Part 3 was published in 1910, but Part 1 has never been published. The parts published included 2,505 species, representing only the Corolliflorae. Professor Conzatti is now actively engaged in the preparation of another work, with the same title, intended to summarize our present knowledge of the vascular plants of Mexico. It will include descriptions, abridged but sufficiently full for purposes of identification, of all the families, genera and species, with their principal synonyms, their ranges and an account of their important economic uses. The treatment of the first 60 families, from ferns to Iridaceae, has already been written. From the nature of the case, the work will be largely a compilation, and the author wishes to obtain the consent of United States botanists to the use in free translation of their published works on the Mexican flora for his book. One of his primary aims is to stimulate the spirit of observation and study among the youth of Mexico by making available to them in their own language a synoptical account of the plants of their native country. In this undertaking he deserves and will undoubtedly receive the support of the botanists of the United States.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A NEW MICROMANIPULATOR

IN some recent work with amebae it was necessary to isolate individual cysts and vegetative forms. Complex devices such as the Chambers or Taylor micromanipulators were impracticable for this purpose. The above apparatus is relatively simple, and has the important advantage of picking up objects from the upper surface of the slide.

Dr. H. C. Hinshaw, formerly of this department, had this manipulator built. It is attached to the binocular body of a Leitz microscope (Fig. 1); and

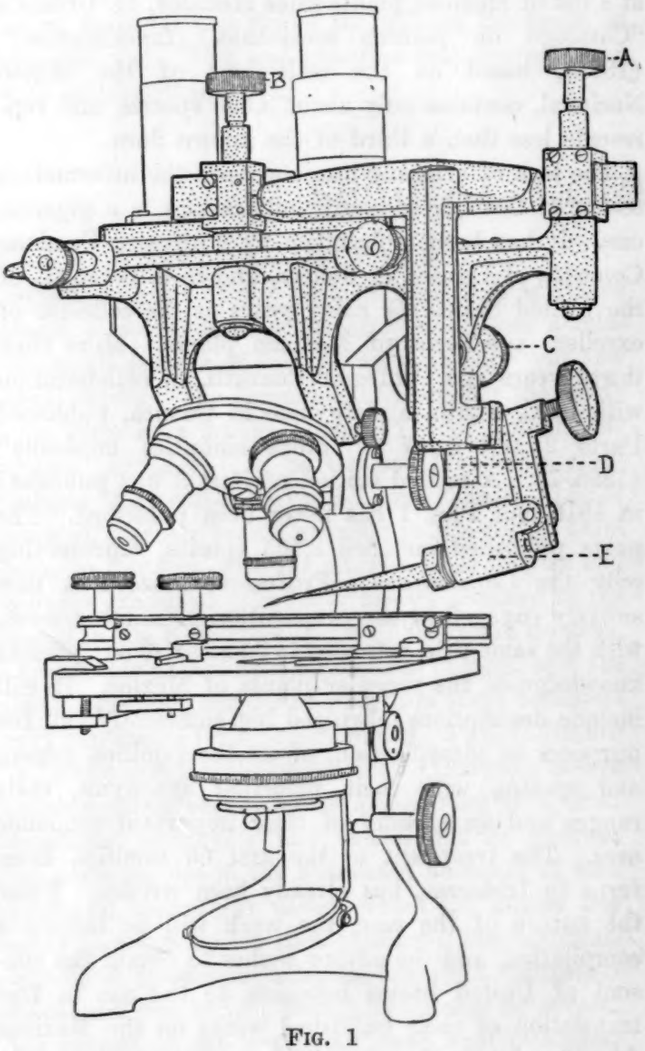

FIG. 1

therefore, since it moves up and down with the adjustment of the microscope, the pipette is always in focus. It is used with the 16 mm or as high as the No. 5 Leitz objective. The manipulator itself is made of aluminum with German-silver springs and screw thrusts. Two vertical screw thrusts (A and B) push against steel balls working in a groove. They give movement in the vertical and one horizontal plane. The horizontal screw thrust (C) pushes against a steel spring (D) and gives movement in the third plane.

Dr. Hinshaw left before perfecting the instrument or working out a satisfactory method of pipette control. After many trials of various devices a new pipette holder was built (E and Fig. 2). It is essen-

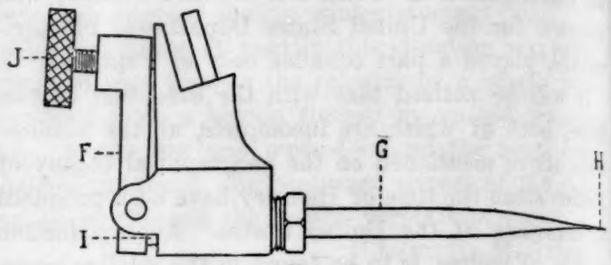

FIG. 2

tially a modification of the Taylor holder, except that it is smaller and makes use of the principle of the lever (F) and removes the screw from the direct line of the pipette. In this way much more delicate control is obtained, and movements from the operator's hand are not transmitted to any great extent. It consists of a brass cylinder into which fits a piece of glass tubing (G) filled with mercury and capped with a piece of rubber. Into the smaller end of this mercury column is cemented the micropipette (H). A metal plunger (I) controlled by the thumb screw (J) pushes against the rubber and so controls the column of mercury, in this way pulling in or expelling an object from the micropipette.

The manipulator combined with the mechanical stage gives a unit which has controlled movements in three planes. Stage movements and the coarse adjustments of the microscope give the coarse adjustments of the unit. The screw thrusts of the manipulator plus the fine adjustments of the microscope control the finer movements.

In the handling of cysts of amebae the instrument is used in the following way: A drop of material containing amebae is put in the lower left-hand corner of the slide. To the right of it are placed two or three drops of Locke's solution. To the right of them is a cover slip with a drop of reagent on its surface. A cyst is picked up by the pipette, the mechanical stage is moved along until the first drop of Locke's is in focus, the cyst is washed, picked up, the stage is moved again, etc., until the cyst is finally in the drop of reagent on the coverslip.

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A SINGING TUBE

DR. ROBESON has recently reported the construction of simple forms of singing tubes.[1] I had the following experience in the spring of 1919, while an undergraduate at Middlebury. Pieces of soft glass tubing of about 10 cm length and 6 to 7 mm diameter were being formed into combustion tubes by sealing and slightly expanding one end. Chancing to blow a bulb of about 20 cm diameter on one of the tubes, I was startled by the immediate production of a singing note of considerable intensity which continued for well over a minute. Moderate heating of the bulb in a Bunsen flame was enough to repeat the phenomenon, but with a lesser intensity because of care exercised to avoid softening of the glass. The tube lay on my desk for several weeks and could be made to sing merely by heating in the flame of a match until its usefulness was ended by accidental dropping. I made several attempts to reproduce it but with no success.

My tube differed from those of Dr. Robeson in these respects: the bore was larger, heating of the bulb rather than of the junction of bulb with tube started the singing, the starting temperature was low, and to the best of my recollection there was no noticeable variation of pitch with change of temperature.

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PURE SMOOTH AND ROUGH COLONY TYPES AT WILL

ANIMAL bacteriologists since 1890 and plant bacteriologists in more recent years have been much interested in the study of two colony types, smooth and rough, produced by many bacterial organisms.

The usual procedure for obtaining the separate colony types for study has been to pick a smooth or rough colony from a poured agar plate produced by the usual bacteriological technique; *i.e.*, a needle transfer of the culture (broth, agar slant or diseased material) to a tube of liquid (broth or water) and sometimes from the first tube to a second tube. A transfer is then made from each dilution tube to melted agar for poured plate examination. When beef infusion broth or agar is used it is usually adjusted to pH 7.0 or neutrality.

From this form of technique the plates may or may not be pure cultures of S or R colonies.

The production, at will, of pure plate cultures of the S and R colony forms of three bacterial organisms has been made possible by a modification of the usual bacteriological technique and it is believed that the purity of types and an abundance of material can be assured for the further study of the two forms.

MODIFIED TECHNIQUE

Make a needle transfer of the culture (broth, agar slant or diseased material) to a pH 6.0 and a pH 7.0 beef infusion broth tube. Then make a second dilution tube from each pH grade of the (1) seeded broth tube. Hold the (2) dilution broth tubes in both pH grades for 18 or 24 hours at room temperature.

After this growth period again make (1) and (2) dilutions from each pH grade of the young culture to a corresponding pH grade of broth. From the last (2) dilution broth tube transfer to a melted pH 6.0 and pH 7.0 beef infusion agar tube for poured plate examination.

This modified technique produces on the plates pure culture of the S or R colonies.

This technique involves three factors necessary to assure the pure S and R colonies. They are as follows:

(a) dilution before and after the young growth period of the organism.

(b) young culture.

(c) pH of the culture medium.

For the smooth colony use only pH 7.0 medium. For the rough colony use only pH 6.0 medium.

The S colony is virulent; the R colony is avirulent.

Attention is called to the fact that an interchange of pH grade from broth to agar plate may result in intermediate types with a corresponding interference in demonstration of virulence and nonvirulence on the host plant.

Reversion of the R type back to the S type will be discussed in the complete manuscript soon to be published.

Virulence was demonstrated by inoculation on the host plants with the pure S colonies and nonvirulence by inoculation with the pure R colonies of *Bacterium tumefaciens,* hop strain, and *Bacillus phytophthorus* organisms.

Later tests with single cell isolations from the S and R types produced in the first *B. phytophthorus* culture study corroborated the evidence produced in the earlier study in every particular.

The single cell progenies were kindly furnished by Dr. A. J. Riker.

The third organism studied was a corn borer parasite as yet unnamed and unpublished.

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[1] SCIENCE, March 6, 1931, p. 265.

SPECIAL ARTICLES

HETEROTHALLISM IN PUCCINIA TRITICINA[1]

CRAIGE[1, 2] discovered in 1927 that the spermatia (pycniospores) of the rust fungi are active functional spores which serve in some way to initiate the sporophyte generation of the rust. Since then other workers have proved by greenhouse investigations that these spores can be used in producing hybrids between physiologic forms of a rust, and a beginning has been made by cytological methods in learning how these spores function. C. F. Andrus, in a paper presented before the Botanical Society of America in December, 1930, reports the occurrence in the gametophyte generation of *Uromyces appendiculatus* (Pers.) Fries of trichogynous hyphae which "are much branched and highly septate organs having their terminus at the epidermis of the host leaf where they project through stomata or between epidermal cells and make contact with spermatia." Nuclei of spermatia enter these trichogynous hyphae and initiate the sporophyte generation.

Puccinia triticina Eriks., the leaf rust of wheat, has its aecial generation upon species of Thalictrum. The sporidium, formed by the germinating teliospore, in the spring, is a haploid spore, and when it falls upon a Thalictrum leaf it germinates, enters directly through the outer epidermal wall, and forms a 4- to 6-cell hypha in the epidermal cell, which in turn gives rise to haploid, intercellular mycelium.

After 6 or 7 days of vegetative growth reproductive activities set in. Spermogonia (pycnia) form at both surfaces of the leaf. A count of a hundred spermogonia in 11-day infections shows that 46 open upon the upper surface and 54 upon the lower.

At the same time that spermogonia are forming, hyphae near the lower surface of the leaf grow into stomatal apertures. A hypha in a stoma is short-lived, but successive hyphae present themselves at the same stoma. It is not uncommon to find 5 or 6 hyphae in the same stomatal aperture, only the last of which is living. In addition to this an occasional hypha at the upper epidermis forces a passageway between epidermal cells to the upper leaf surface. In older leaves this development at the upper epidermis is limited. In infections on young tender leaves it is more abundant. There may even be an extensive subepidermal growth of mycelium giving rise to groups of upright hyphae that push up to the surface. Hyphae reaching the lower or upper leaf surface through stomata or between epidermal cells are regarded as receptive hyphae.

In the substomatal air space, beneath a stoma occupied by one or more receptive hyphae, the hyphae grow and branch rapidly, forming a dense little nest of cells—the beginning of an aecium. If, as not infrequently happens, practically all the stomata in an infected area are occupied, there is not room for so many aecial primordia, and only a part of them develop. Over a large vein, where stomata do not occur, aecial primordia are absent.

Puccinia triticina is heterothallic. A monosporidial infection may bear both spermogonia and receptive hyphae, but, if kept isolated, it will remain sterile. Unless spermatia are brought to it from another and different infection, the aecia remain haploid and after the first differentiation into an upper area of small dense cells and a lower area of large empty cells, the whole aecium gradually degenerates and dies. With rare exceptions the sterile aecium consists of uninucleate cells from beginning to end.

A comparative study of a number of young infections of the same age shows that some have many spermogonia and few receptive hyphae; others have comparatively few spermogonia and more receptive hyphae; and a few have no spermogonia whatever and abundant receptive hyphae. The intermediates in this series are more numerous than the extremes, although some, at first classed as intermediates, have since been proved to be of multisporidial origin.

This is not just a temporary condition of young infections. In one sterile infection 42 days old there were 103 spermogonia and only 23 small sterile aecia. In another large sterile infection from the same lot of material there were over 200 sterile aecia and no spermogonia whatever. Moreover, in this latter, the average size of the aecium was much greater than in the spermogonial infection. The infections of *Puccinia triticina* can be arranged into a series with an almost exclusively spermogonial type at one end and a completely aecial type at the other.

Before fertilization, the receptive hyphae, like the haploid mycelium producing them, consist of uninucleate cells. When fertilization takes place, the receptive hyphae at the stomata are found crowded with nuclei. Two to 6 nuclei are common and as many as 11 nuclei in a cell have been seen. Growth from these cells permeates the aecium. The young fertile aecium grows vigorously and is composed of

[1] J. H. Craigie, "Experiments on Sex in Rust Fungi," *Nature*, 120: 116–117, 1927.

[2] J. H. Craigie, "Discovery of the Function of the Pycnia of the Rust Fungi," *Nature*, 120: 765–767, 1927.

a matrix of haploid cells interspersed throughout with cells containing 2 or more nuclei. The aecium becomes differentiated into a lower half of large vacuolated cells, which later die, and an upper half of smaller denser cells. In this upper area multinucleate cells are abundant. The number of nuclei varies, ranging in extreme cases to 15 or 20 per cell. With further growth and cell division the number of nuclei per cell decreases. From this mass cells grow down to form the sporogenous layer of "basal" cells. Young basal cells contain from 2 to 8 nuclei. The extra nuclei are used in forming the first spores and by the time the spore chains are well started the basal cells are regularly binucleate.

The question of the effectiveness of the receptive hyphae that grow to the upper surface of the leaf is still an open one. Aecia occur that open on the upper surface, but they are uncommon. Either fertilization of the upper receptive hyphae is rare, or those that are fertilized grow to the lower surface before developing further. So far this has not been observed.

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CALIFORNIA AGRICULTURAL EXPERIMENT STATION

THE REDIA OF THE GASTEROSTOMES[1]

AN intermediate generation has been found in the life history cycle of the trematode order *Gasterostomata*, thereby bringing this form into line with normal life histories of other digenetic trematodes. The adult of this generation, the redia, is found in abundance in the lumen of the young mother-sporocysts. Young redia dissected from the mother-sporocysts are very active swimmers due to the covering of long cilia over the entire surface of the body. Older specimens indicate a loss of cilia followed by a coating of spines which are similar in character to the final adult. Two eyes are present. The redia is hermaphroditic. The testis is large, median in position with an extensible penis. In a live redia, mature active spermatozoa have been observed. The ovary is small, below the testis on the left side. Laurer's canal is long and apparently functions in cross-fertilization as a sperm-duct leading to the ovary. The vitelline complex in two lateral rows is very well developed. Eggs are shed through a short oviduct into the cavity of the mother-sporocyst and give rise to cercariae.

The origin of the redia was found to be in the gonads of the mother-sporocyst, and localized in the distal ends of the branches. The testis is large and situated below the tip of the branch previous to the expanded portion of the lumen. The ovary in the mother-sporocyst of *Bucephalus pusillum* appears in the form of "stroma." In *B. elegans* the ovary is located in a "plug" extending downwards into the lumen. This "plug" is composed of the ovary and nutritive glands, both in the form of "stroma" which, as development proceeds, extend for a considerable distance through the lumen even in older branches heavily packed with cercariae.

Spermatogenesis has been worked out in detail for all three generations; in the mother-sporocyst, redia and final adult.

It is therefore concluded that each of the three generations starts with a fertilized egg and gives rise to hermaphroditic "adults." Maturation with polar bodies and reduction is evident. There is no parthenogenesis or metagenesis. The life history of the trematodes as witnessed in this order is simple, with comparable embryological and larval stages in each of the three generations. The differences in the adults undoubtedly has evolutionary significance and is probably due to parasitism: first, within a mollusk; second, within the mother-sporocyst, and third, within the vertebrate.

Other species, not related to the gasterostomes are being studied by the author to find out how universal this method of reproduction is, among the class *Trematoda*. Material to be examined must be young before the reproductive stage is over and before the nutritive phase increases to confuse observation. Completely known life cycle material is preferable. Differential staining is advisable.

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[1] Contribution from the Zoölogical Laboratory of the University of Michigan.

VARIATIONS IN THE EVENING PRIMROSE INDUCED BY RADIUM

GENETICISTS are now aware that x-rays and radium are agents by which genetic changes, both genic and chromosomal, may be produced. However, in the several years since 1927, in which many investigators have published on the genetic effects of irradiation on both plants and animals, nothing, in so far as I am aware, has appeared dealing with the irradiation of the evening primrose. For the past three years the writer has been making such an investigation, using radon (radium emanation) in the treatment of *Oenothera Lamarckiana* and *Oe. franciscana*, a preliminary account of which appears here.

The method of treatment was to insert an unfiltered tube of radon parallel with the buds in a flowering cluster, thus treating buds in all stages of development at distances varying from direct contact to 4 cm. As the flowers opened after treatment they were

self-pollinated. Eight irradiations of *Lamarckiana* and four of *franciscana* were made, the tubes of radon used varying from 7 millicuries to 17 mc, and the times of application from four to twenty hours. At the same time, flowers on another shoot of the same plant were selfed (being adequately protected by lead) to provide control material. In all cases, control families have shown only the usual species characteristics.

The immediate effects of the radium treatment were a development after two days or less of a necrotic area in the cluster where the radon tube had rested, an abscission of buds thus affected regardless of size or age unless the injury was very slight, and a necrosis of all buds in the stages of meiosis or younger. The rate of flowering, the size of the flowers, and the fertility, chiefly of the pollen, were affected to a greater or less degree depending on the dosage.

Single capsule sowings were made in 1930 of the seed from treated buds, making 95 families of *Lamarckiana* origin and 29 families of *franciscana* origin. The percentage germination was lowered in those cultures which had the heavier dosages. As the seedlings developed their rosette characters it was found that many unclassifiable leaf shapes, sizes and peculiarities existed in both *Lamarckiana* and *franciscana*. In the majority of cases, the leaves were very much distorted and retarded in growth. In some cases, however, quite new and distinct leaf features were present. In *Lamarckiana* material small, weak plants were rather common in irradiated cultures, some with very unusual leaf characters; mottled, pale green, reduced size, wiry, irregular, no crinkling, excessive crinkling and the like. No two were identical. In the *franciscana* cultures the same general conditions were present, although the percentage of abnormal forms was lower. However, the most striking of the radium variants have been in *franciscana* material.

It is unfortunate that the vast majority of the atypical forms mentioned above were too weak to survive field conditions, either dying or not coming into bloom. A few of the stronger ones did bloom, however, and have proved very interesting plants. The abnormal characteristics manifest in the rosette condition continued and new ones peculiar to the mature condition appeared. As a rule, the flowering tip was smaller, bore fewer flowers, and had quite a high percentage of buds drop before blooming. The flowers were generally smaller, distorted in most features, and pollen sterility was much in evidence. Some few plants were wholly sterile.

Breeding work, in so far as was possible, was done with the above forms. The progenies are now being grown. It is known definitely that one of the abnormal types found in *Lamarckiana* when selfed throws a progeny in which the parent type composes approximately one-fourth (7 in 27) of the population. This type is a little more viable than the majority. It is a form with dull coarse leaves, free from crinkling with very irregular margins, sometimes toothed. The behavior at present suggests some unbalanced chromosome condition.

One of the more viable of the atypical *franciscana* forms was selfed and its progeny grown this summer. An entirely new form has appeared, extremely weak with very linear mottled leaves. Twenty-three of these plants have appeared in a population of 64, the frequency suggesting a 1:2 ratio. It is disappointing that this new form is not viable under field conditions. Selfings are being made among the 41 other plants in the hope of discovering a few heterozygotes which will give the same form next year.

Many of the normal plants in irradiated cultures were selfed in the summer of 1930, so that any recessive condition induced by radium treatment might appear in their progeny this summer. In one case, that of a *franciscana* plant, an abnormal type has appeared. In a population of 25 plants, four are of this new type, characterized chiefly by the tiny, much distorted crinkled condition of the leaves on the flowering tip.

It is intended to continue the genetical investigation on these new forms occurring in the progenies from radium-treated buds, in so far as the conditions of reduced fertility will permit. It is also planned to investigate the chromosomal conditions in the radium variants.

I wish to acknowledge the invaluable aid of those who are making this work possible: Dr. Halsey J. Bagg, of Memorial Hospital, New York City, who has kindly supplied me with the radon, and Dr. George H. Shull, of Princeton University, who has been very helpful in his guidance and criticism.

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